1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (270)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (290)	116 Lv (293)	117 Ts (294)	118 Og (294)

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (266)

constants

$R = 0.08206$ L atm/mol K

$R = 8.314$ J/mol K

$F = 96485$ C/mol e^-

$N_A = 6.022 \times 10^{23}$ /mol

$h = 6.626 \times 10^{-34}$ J·s

$c = 3.00 \times 10^8$ m/s

$g = 9.81$ m/s^2

conversions

1 atm = 760 torr

1 atm = 101325 Pa

1 atm = 1.01325 bar

1 bar = 10^5 Pa

°F = °C(1.8) + 32

K = °C + 273.15

conversions

1 in = 2.54 cm

1 ft = 12 in

1 yd = 3 ft

1 mi = 5280 ft

1 lb = 453.6 g

1 ton = 2000 lbs

1 tonne = 1000 kg

1 gal = 3.785 L

1 gal = 231 in^3

1 gal = 128 fl oz

1 fl oz = 29.57 mL

standard potentials at 25 °C

	$E°$ (V)
$F_2(g) + 2\,e^- \rightleftharpoons 2\,F^-(aq)$	+2.87 V
$Ce^{4+}(aq) + e^- \rightleftharpoons Ce^{3+}(aq)$	+1.61 V
$Cl_2(g) + 2\,e^- \rightleftharpoons 2\,Cl^-(aq)$	+1.36 V
$O_2(g) + 4\,H^+(aq) + 4\,e^- \rightleftharpoons 2\,H_2O(\ell)$	+1.23 V
$Pd^{2+}(aq) + 2\,e^- \rightleftharpoons Pd(s)$	+0.92 V
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80 V
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77 V
$Cu^{2+}(aq) + 2\,e^- \rightleftharpoons Cu(s)$	+0.34 V
$2\,H^+(aq) + 2\,e^- \rightleftharpoons H_2(g)$	**0.00** V
$Fe^{3+}(aq) + 3\,e^- \rightleftharpoons Fe(s)$	−0.04 V
$Pb^{2+}(aq) + 2\,e^- \rightleftharpoons Pb(s)$	−0.13 V
$Ni^{2+}(aq) + 2\,e^- \rightleftharpoons Ni(s)$	−0.23 V
$Fe^{2+}(aq) + 2\,e^- \rightleftharpoons Fe(s)$	−0.44 V
$Zn^{2+}(aq) + 2\,e^- \rightleftharpoons Zn(s)$	−0.76 V
$Al^{3+}(aq) + 3\,e^- \rightleftharpoons Al(s)$	−1.66 V
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	−3.05 V

This exam should have exactly 20 questions. Each question is equally weighted at 5 points each. Bubble in your answer choices on the bubblehseet provided. Your score is based on what you bubble on the bubblesheet and not what is circled on the exam.

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1. What are the oxidation numbers of Na, S, and O in Na_2SO_3?

● a. Na = 1, S = 4, O = -2

b. Na = 1, S = 2, O = -2

c. Na = 2, S = 2, O = -2

d. Na = 2, S = 4, O = -6

e. Na = 2, S = 2, O = -6

Explanation: It should be known that the oxidation number on Na is 1 and oxygen is -2. From there, calculate the oxidation number of sulfur:

$0 = 2(1) + x + 3(-2)$

x = 4

---

2. Identify the change in oxidation number for nitrogen in the conversion of N_2 to NO_2^-. Is this process a reduction or oxidation?

● a. +3, oxidation

b. -3, reduction

c. +4, oxidation

d. +4, reduction

e. +6, reduction

f. +5, oxidation

Explanation: N_2 is a standard state diatomic with an oxidation number equal to 0. Nitrogen has an oxidation state equal to +3 in nitrite (-1 = 3 + 2(-2)). This corresponds to an oxidation reaction.

---

3. What is the balanced redox equation represented by the following shorthand notation:

$$Pt \,|\, H_2 \,|\, H^+ \,||\, Al^{3+} \,|\, Al$$

● a. $3H_2 + 2Al^{3+} \rightleftharpoons 6H^+ + 2Al$

b. $2H_2 + 3Al^{3+} \rightleftharpoons 2H^+ + 3Al$

c. $H_2 + Al^{3+} \rightleftharpoons H^+ + Al$

d. $6H^+ + 2Al \rightleftharpoons 3H_2 + 2Al^{3+}$

e. $2H^+ + 2Al \rightleftharpoons 3H_2 + 2Al^{3+}$

Explanation: Write the half-reactions:

$H_2 \rightleftharpoons 2H^+ + 2e^-$

$Al^{3+} + 3e^- \rightleftharpoons Al$

multiply each reaction reach the least common multiple for the number of electrons, which would be 6 in this case:

$3H_2 + 2Al^{3+} \rightleftharpoons 6H^+ + 2Al$

---

4. In acidic conditions, iron(II) oxide and dichromate will react to form iron(III) ions and chromium ions as shown in the unbalanced redox equation below:

$$FeO + Cr_2O_7^{2-} \rightleftharpoons Fe^{3+} + Cr^{3+}$$

What is the sum of the two coefficients of the product cations (Fe^{3+} and Cr^{3+}) in the properly balanced equation?

a. 3

b. 2

●c. 8

d. 6

e. 4

Explanation: Start with the half-reactions and follow the steps:

1. Balance the iron and chromium

2. Balance oxygen with water

3. Balance hydrogen with H^+

4. Balance the charges on the left and right of the half-reactions with electrons

5. Balance the half-reactions with the least common multiple of the number of electrons

The balanced equation is:

$$26H^+ + 6FeO + Cr_2O_7^{2-} \rightleftharpoons 6Fe^{3+} + 2Cr^{3+} + 13H_2O$$

---

5. Elements in their standard state have an oxidation number equal to...

●a. 0

b. +1 for monatomics and +2 for diatomics

c. the column in the periodic table

d. the column in the periodic table for metals and eight minus the column in the periodic table for nonmetals

Explanation: The oxidation number for all elements in their standard state is equal to zero.

---

6. What is the voltage of a standard voltaic cell made from the following two half reactions:

$$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$$
$$Pb^{2+} + 2e^- \rightleftharpoons Pb$$

a. 1.26 V

b. -1.26 V

c. 3.03 V

●d. 1.49 V

e. 0.31 V

Explanation: Arrange the half-reactions to give you a positive cell potential:

1.49 V = 1.36 V - (-0.13 V)

---

7. What is the standard potential of the strongest voltaic cell you can make using the following half reactions?

$$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$$

$$Cu^{2+} + 2e^- \rightleftharpoons Cu$$

$$Fe^{3+} + 3e^- \rightleftharpoons Fe$$

$$Li^+ + e^- \rightleftharpoons Li$$

Note: use the standard potentials as your reference for "strongest."

a. -1.36 V

b. 3.05 V

c. 1.36 V

●d. 4.41 V

e. 1.40 V

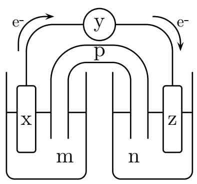
f. 5.40 V

Explanation: Select the Cl_2 half reaction as your cathode and Li as your anode:

4.41 V= 1.36 V - (-3.05 V)

---

8. (part 1 of 2): Consider the electrochemical cell diagram shown below which is running spontaneously with the electron flow direction as shown. Choose the answer the correctly identifies the salt bridge and the flow of cations in cell compartment n.



a. $x + y + z =$ salt bridge; cations do not flow

b. $m =$ salt bridge; cations flow towards x

c. $p =$ salt bridge; cations flow towards p

●d. $p =$ salt bridge; cations flow towards z

e. $y =$ salt bridge; cations flow towards z

Explanation: $p =$ salt bridge; cations will flow towards the cathode which has to be the z component due to the fact electrons are flowing towards it in the external circuit

---

9. (part 2 of 2): For the previously shown cell diagram, what is the assigned charge on the component labeled x

●a. negative

b. positive

c. no charge

Explanation: Electrons always travel from anode to cathode. For the diagram given, the electrons travel from x (anode) to z (cathode). For a voltaic cell (it says spontaneous electron flow), the anode is negative (x) and the cathode is positive (z).

---

10. What is the standard potential for the following cell?

$$Ag \,|\, Ag^+ \,||\, Zn^{2+} \,|\, Zn$$

a. 2.36 V

b. -0.72 V

●c. -1.56 V

d. 1.56 V

e. -2.36 V

Explanation: Identify the anode and cathode and solve for the potential. It is worth recognizing from the shorthand notation and half reactions that this is an electrolytic cell.

-1.56 V = -0.76 V -(+0.80 V)

---

11. Consider the following concentration cells:

$$Pd \,|\, Pd^{2+}\,(0.050\,M) \,||\, Pd^{2+}\,(0.050\,M) \,|\, Pd$$

$$Ni \,|\, Ni^{2+}\,(0.050\,M) \,||\, Ni^{2+}\,(0.050\,M) \,|\, Ni$$

Will the palladium concentration cell have a potential stronger than, weaker than, or equal to the nickel concentration cell?

a. stronger than

b. weaker than

●c. equal to

Explanation: The potential of a concentration cell is strictly concentration-dependent, as long as the charges on compared ions are equal. Both the palladium and nickel cells will have the same potential.

---

12. What is the cell potential for the following nonstandard cell?

$Ni\,|\,Ni^{2+}\,(0.023\,M)\,||\,Ni^{2+}\,(0.068\,M)\,|\,Ni$

a. -202 mV

b. 27.9 mV

●c. 13.9 mV

d. -13.9 mV

e. -27.9 mV

f. -216 mV

Explanation: $E = -\frac{0.05916}{n} \times \log\frac{[Ni^{2+}]_{anode}}{[Ni^{2+}]_{cathode}}$

$0.0139257204\,V = -\frac{0.05916}{(2)} \times \log\frac{0.023}{0.068}$

$= 13.9$ mV

---

13. Which of these is NOT a characteristic you would want for the primary cells powering your television remote?

a. The cell maintains a stable voltage for as long as possible.

●b. The cell rapidly discharges its full potential.

c. The cell has a surface area proportional to the amount of current you want to provide to an external circuit.

d. The cell is voltaic.

Explanation: The incorrect statement here is that the cell rapidly discharges. Ideally, the cell will supply a constant current for as long as possible.

---

14. The lead acid battery (aka car battery) has lead in various oxidation states and compounds. Which of the following species listed is the *active* material at the cathode of a lead acid battery as it is being discharged?

a. $Pb_2O_3(s)$

b. $Pb^{2+}(aq)$

c. $Pb(s)$

●d. $PbO_2(s)$

e. $PbSO_4(s)$

Explanation: The cathode reaction is:

$$PbO_2(s) + 3H^+(aq) + HSO_4^-(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(\ell)$$

---

15. Which type of battery uses the chemistry shown in the following shorthand notation?

$Zn(s)\,|\,ZnOH(s)\,|\,KOH(aq)\,||\,KOH(aq)\,|\,Mn_2O_3(s)\,|\,MnO_2(s)\,|C(s)$

●a. alkaline cell

b. lithium ion

c. fuel cell

d. car battery

e. NiCd

Explanation: This reaction is the chemistry for the alkaline cells.

---

16. You wish to electroplate 1.00 g of gold on a piece of jewelry from a concentrated solution of Au^{3+} ions. What current is needed to achieve the reaction in 10 hours?

a. 27.2 mA

●b. 40.8 mA

c. 1.36 mA

d. 102 mA

e. 147 mA

Explanation: Use Faraday's law: $\frac{I \cdot t}{n \cdot F} = \text{mol metal}$

mol Au = 1.00 g $\times \frac{\text{mol}}{196.97\,\text{g}}$

= .005076915 mol Au

$n = 3$

$F = 96485$

$t = 36000$

Rearrange to solve for current, I:

$I = \frac{(.005076915)(3)(96485)}{36000}$

$I = .0408\,A = 40.8\,mA$

---

17. Conceptually, Faraday's law tells us that the number of moles of metal plated is equal to the charge applied divided by the charge required to plate one mole of metal. How much charge will it take to plate out one mole of cobalt metal from Co^{2+} ions?

a. 96485 C

●b. 2×96485 C

c. 3×96485 C

d. $N_a \times 96485$ C

Explanation: This is asking for the denominator of Coulomb's law, which is the amount of charge required to plate on mole of cobalt. This is simply: nF or 2×96485 C .

---

18. What drives a voltaic cell?

●a. the spontaneity of the redox reaction

b. the external power source

c. the push of electrons from cathode to anode

d. the heat supplied by the chemical reaction

Explanation: A voltaic cell is driven by the spontaneity of the redox reaction.

---

19. Which of the following half reactions would require an inert electrode?

a. $Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$

b. $Li^+(aq) + e^- \rightleftharpoons Li(s)$

●c. $F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$

d. $Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$

e. $Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$

Explanation: The purpose of an inert electrode is to provide a conductive metal to a reaction that does not inherently involve a conductive solid metal. Out of these choices, this corresponds to:

$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$

---

20. Which of the following factors is the *main* one that governs the maximum amount of current that a battery can deliver?

●a. the surface area of the electrodes

b. the concentration of the electrolyte

c. the salt used in the salt bridge

d. the working voltage of the battery

e. the conductance of the metal electrodes

Explanation: More electrons can be passed at one time (electric current) when there is more active surface from which to transfer. Increasing surface area will increase the maximum current possible for any battery.

Remember to bubble in ALL your answers BEFORE time is called. Double check your name, uteid, and version number before you turn in your bubblesheet. You must keep your exam for future reference. Please do not lose it. We will not replace it.